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RECENT ADVANCES IN LEWIS AEROPROPULSION FACILITIES

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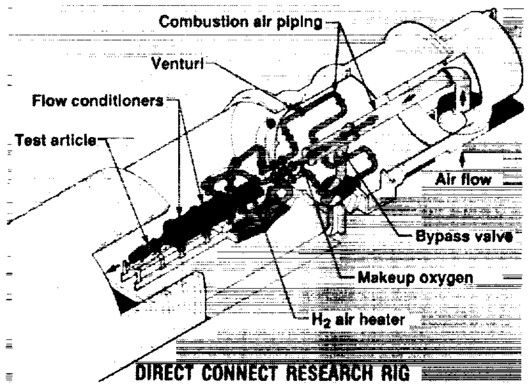
Guided by the aeropropulsion strategic plan, Lewis has been systematically refurbishing and upgrading its aeropropulsion facilities through a combination of R&D and construction of facilities (CoF) funding. Currently, much of the work is being accomplished as a part of the NASA Aeronautical Facility Revitalization Program. The total effort is addressing issues of improved flight simulation, improved productivity, capability to support advanced aeropropulsion systems, increased computational capability, and recertification. This paper presents an overview of the changes brought about by that effort.

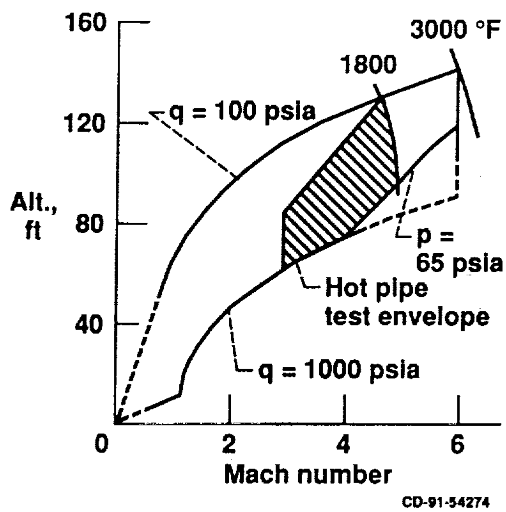
PSL-4 Hypersonic Modification

Operating Envelope

Hot pipe test conditions

- Temperature 70 – 1900 °F
- Pressure 10 – 65 psia
- Air flow 19 – 118 pps
- Hydrogen flow 0.05 – 0.68 pps



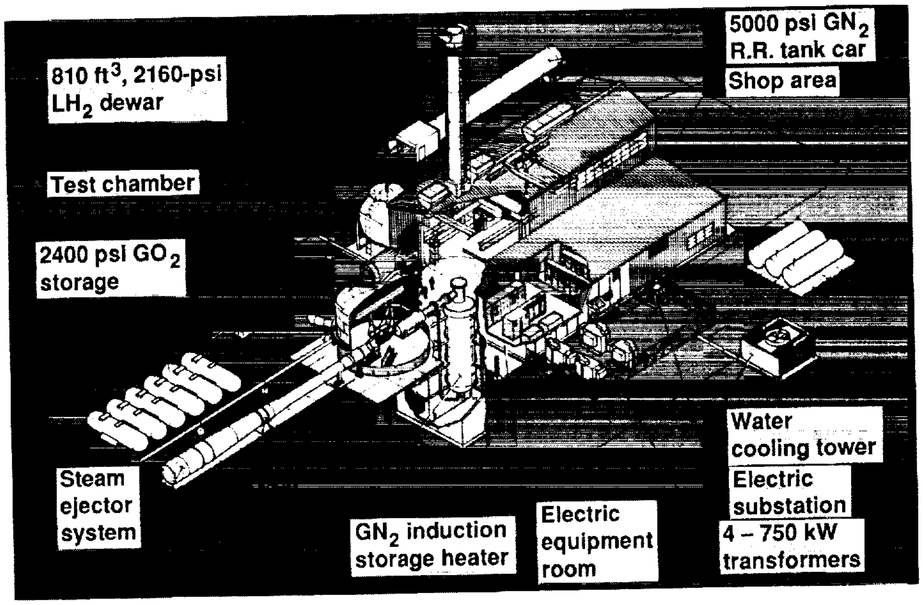


FLIGHT SIMULATION

A number of changes and additions have already been accomplished, and still more are in process, to provide a better simulation of higher Mach numbers. Figure 1 shows an addition made to the Propulsion Systems Laboratory cell 4, a full-scale turbine engine altitude cell. An in-line hydrogen fueled air heater was added to raise the model air supply (118 lb/sec) temperature to 3000 °F at 100 psia. This provides simulation up to Mach 6 in a direct-connect mode. Oxygen replenishment is provided to make up for depletion by the combustion process.

Plum Brook Hypersonic Tunnel Facility

Wind Tunnel Revitalization Program



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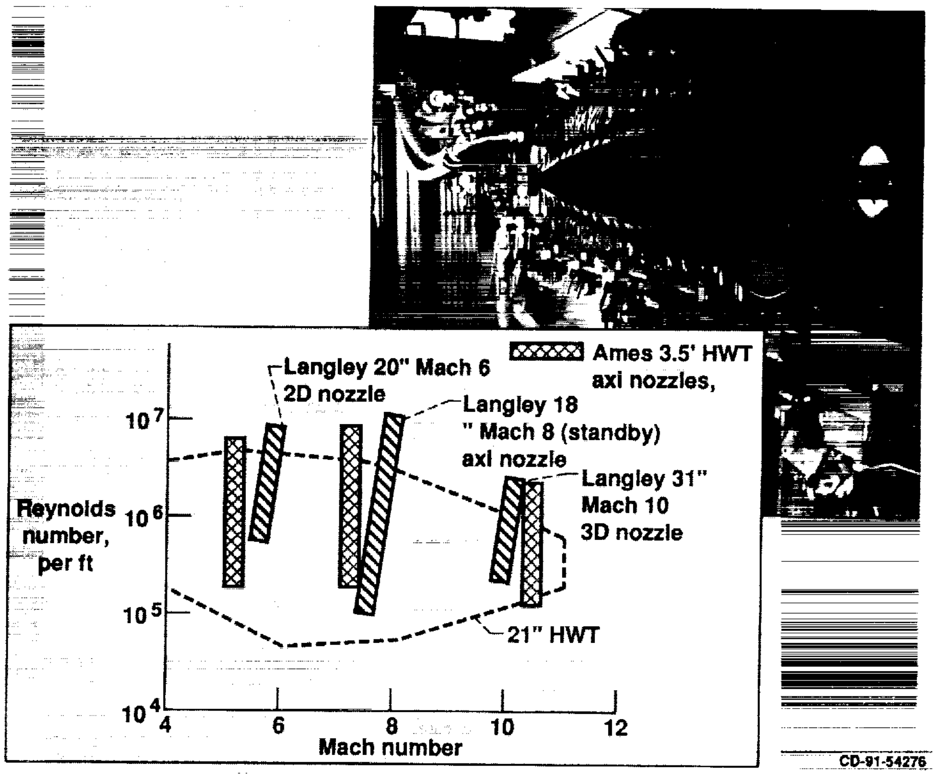
The Hypersonic Tunnel Facility (HTF) is being reactivated at Lewis' Plum Brook test site. This unique, indirectly heated, free-jet facility provides Mach 5, 6, and 7 test capability with a 42-in. nozzle. Because of the indirect heating, the air stream is not contaminated by combustion products and therefore provides a better simulation for propulsion testing. The test cabin can accommodate test articles up to 10 ft long, and a steam ejector system can provide altitude simulation to 125 000 ft. Final checkout tests for this facility are scheduled for early 1993.

21 - In. Hypersonic Wind Tunnel

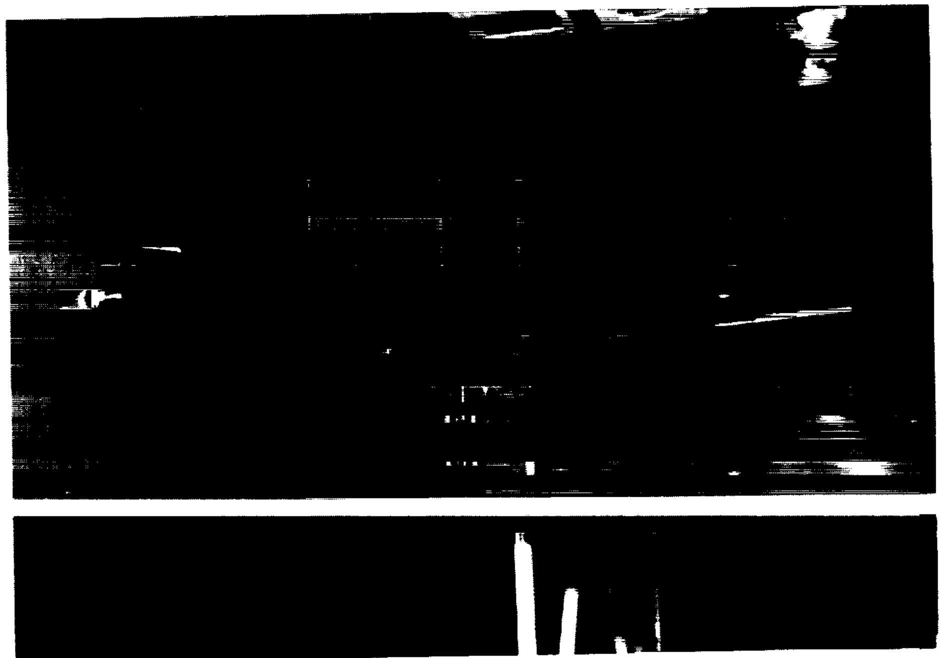


In 1994, rebuilding and activation of a 21-in. hypersonic wind tunnel will begin, with IOC planned for 1996. This facility originally located at the Jet Propulsion Laboratory has a demonstrated superior flow quality and will be used initially to validate codes in the hypersonic regime.

Improvements are also being made in lower flight speed simulations. For example, in the 8- x 6-ft Supersonic Wind Tunnel/9- x 15-ft Low Speed Wind Tunnel complex, aerodynamic refinements are in process to improve the flow quality in the test sections. This work, to be completed in 1992, has the following goals:

Mach number	± 0.001
Flow angularity	$\pm 0.1°$
ΔV/V (8x6 test section)	$\pm 0.25\%$

Half-Span Model Installed in Icing Research Tunnel for Lift-Drag Tests



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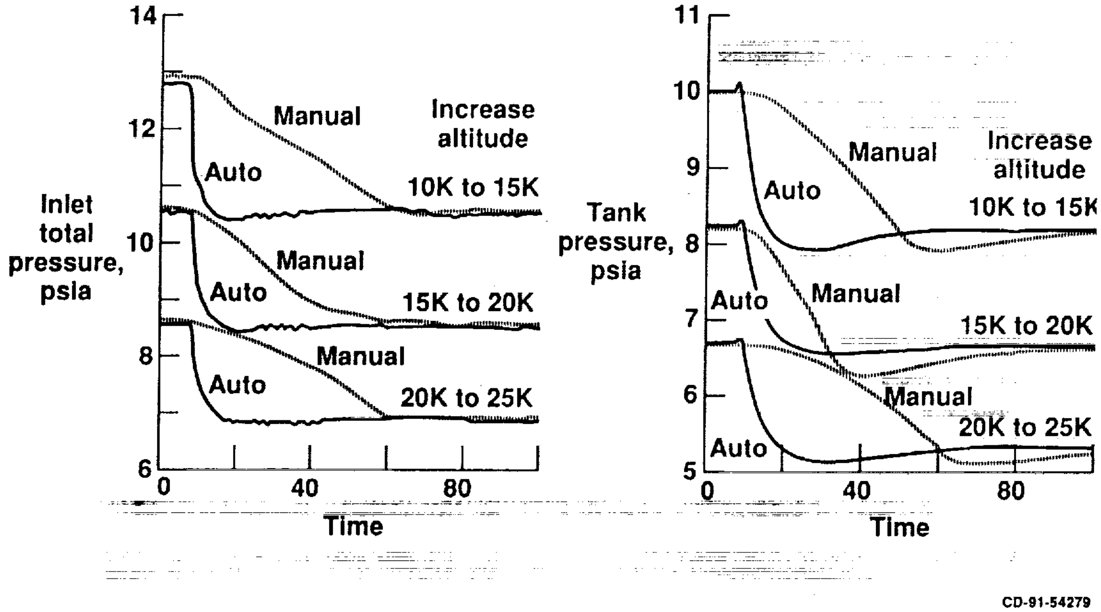
PRODUCTIVITY

The main thrust of NASA's Aeronautical Facility Revitalization Program is to refurbish NASA's aging aero facilities and improve their productivity and effectiveness. At Lewis, in addition to the general refurbishment, which should reduce unplanned outages, other planned changes and additions will improve productivity and test effectiveness. All major aero facilities will be equipped with separate model buildup and checkout rooms. This will allow models to be thoroughly debugged and prepped prior to installation in the test section, and will facilitate the handling of classified hardware. The control systems in these facilities are being upgraded to more modern, digital distributed control systems. These systems offer higher reliability, improved test point accuracy, reduced operator fatigue, and improved transient capability. An example of what these systems can do is shown above. The entire take-off roll, including rotation, of the full size aircraft was simulated in order to study the effects of deicing fluids on lift and drag. The tunnel air speed, temperature, and liquid water content and the angle of attack of the model were all preprogrammed in the control system, which provided very precise control and repeatable test conditions.

Automated and Manual Control Responses in the Propulsion Systems Laboratory

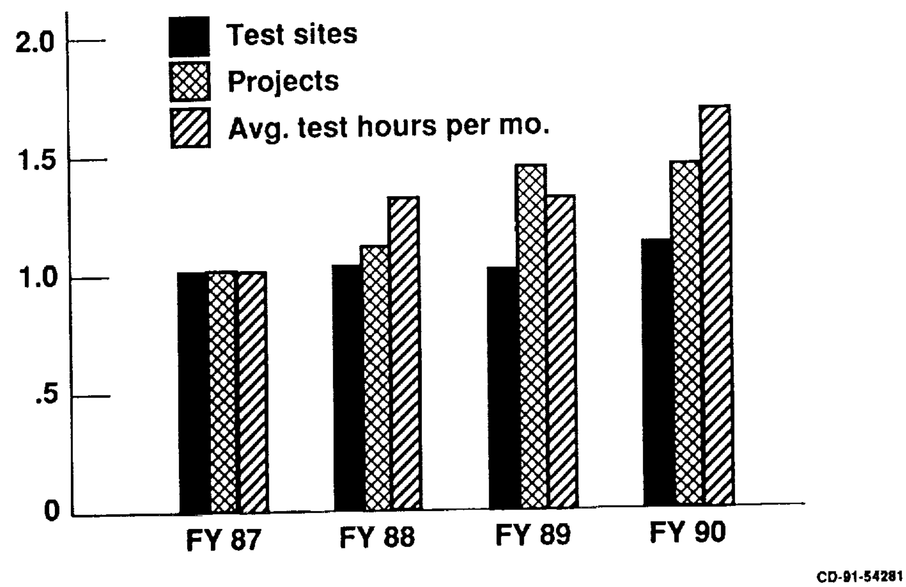


The figure depicts the improvements made in full scale turbine engine transient test capability. Shown are typical response times for the old, semiautomated system and what is possible with the new controls in terms of simulated flight Mach number and altitude.

The turbomachinery component cells have also benefited from the aeropropulsion facility general refurbishment. The old motor-generator variable frequency (VF) system, used to power variable speed drives for compressor testing, has been replaced with a new, solid-state VF system. The new VF system has greatly improved stability and resetability, providing an order of magnitude improvement in these parameters over the old system. The refrigerated air supply to the component test cells has been reactivated and updated to a turboexpander system capable of supplying air as low as -50 °F. This capability permits testing at high corrected speeds while at low mechanical speeds (and stresses).

Aeropropulsion Resource Utilization

(Normalized to FY '87)



The integrated effects on productivity for the major Lewis aeropropulsion facilities as a result of a number of incremental improvements are shown above. The data has been normalized to FY 1987 as a base year.

High Energy Fuel and Oxidizer Supply System in Aeropropulsion Facilities

Facility	System and capability
10x10 Supersonic Wind Tunnel	GH_2 – 0.66 lb/sec at 1200 psia
8x6/9x15 Wind Tunnel	GH_2 – 1.0 lb/sec at 1500 psia
PSL	GH_2 – 2.75 lb/sec at 1000 psia
	GO_2 – 3.0 lb/sec at 100 psia 10.0 lb/sec at 300 psia
CE-9B	GH_2 – 0.12 lb/sec at 500 psia
PLF	GH_2 – 0.12 lb/sec at 1000 psia
HTF	GH_2 – 350,000 scf at 2400 psia
	GO_2 – 500,000 scf at 2400 psia
	LH_2 – 6000 gal

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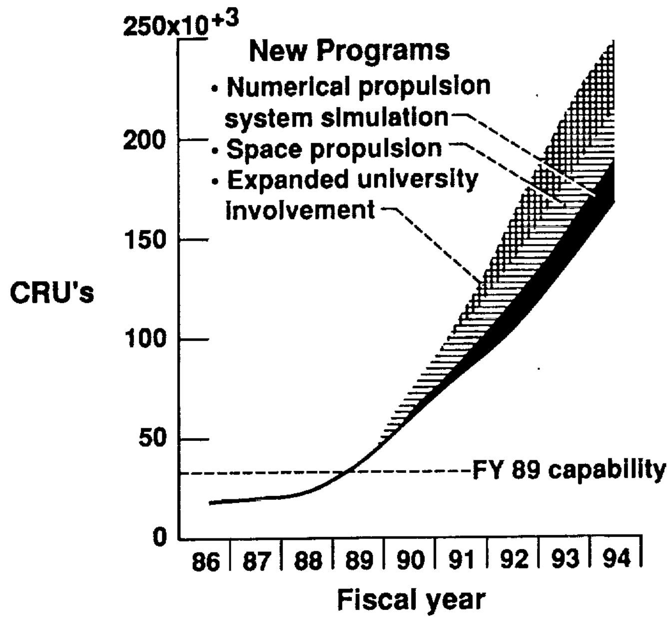
ADVANCED SYSTEMS

Lewis has long had a demonstrated capability to handle a variety of high energy propellant combinations safely in its rocket test cells. Drawing on this experience, hydrogen and oxygen supplies for the test article have been added to some of the aeropropulsion facilities to meet the needs of NASP and other high speed propulsion systems. A summary of these systems and their capabilities is shown above.

Supercomputing Requirements Based on Current and New Programs



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COMPUTATIONAL CAPABILITY

Technology development at Lewis thoroughly integrates computation and experiment, with computing guiding experiment test planning and the experiment providing data for code validation. In 1988, Lewis undertook an assessment of its scientific computing needs. Several facts came to light:

(1) The ADP environment must be a balance between centralized and distributed computing systems in order for Lewis to do its job.

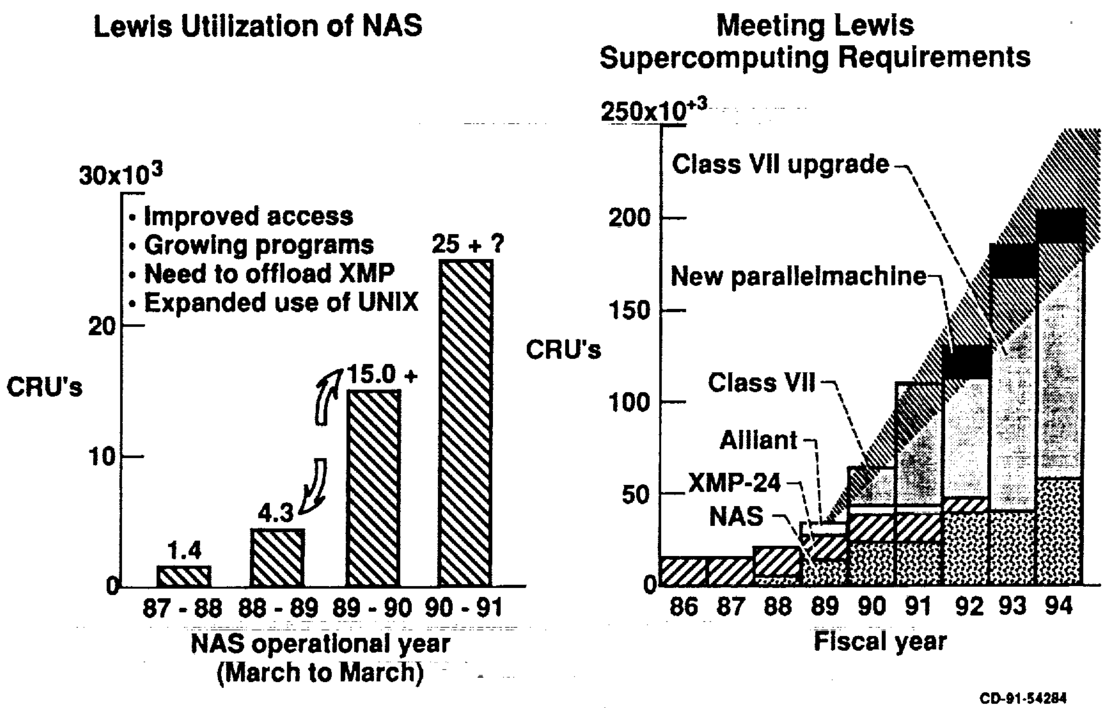
(2) There is a growing need for interactive graphics.

(3) Lewis was facing a saturation of its supercomputing capability.

(4) There is a shortage of engineering workstations.

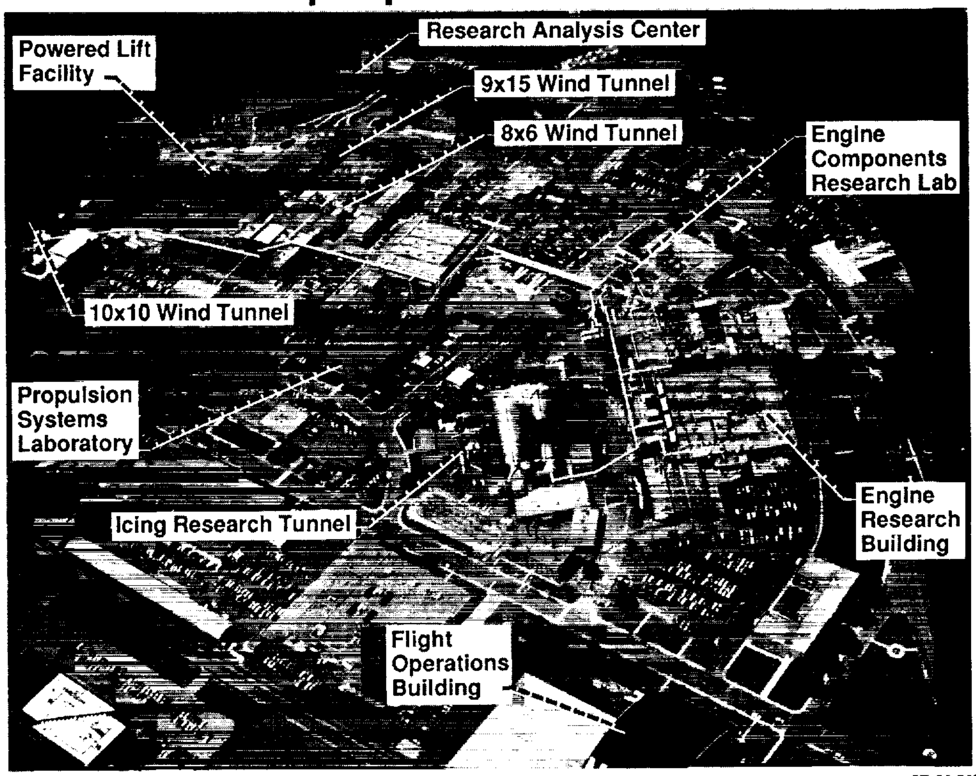
The saturation/shortfall in scientific computing is illustrated above.

Computational Facilities



In 1989, Lewis developed and implemented a long range plan to meet its computing needs. First, Lewis' share of the available time on the Numerical Aerodynamic Simulation (NAS) facility was increased. Second, a new class VII supercomputer was purchased and became operational in July 1990. This machine supplemented the existing CRAY XMP, and further upgrades are planned for the future. Third, buys of engineering workstations was increased. This plan, when fully implemented, should meet Lewis' scientific computing needs through the 1990's.

Aeropropulsion Facilities



RECERTIFICATION

The average age of the Lewis aeropropulsion facilities is now very nearly 40 years. Many systems are unique and not built to ASME or other national consensus codes. In addition to the general refurbishment, requalification of the basic structures and supporting systems is necessary in order to assure continued availability. Lewis is now in its 10th year of a 15 year recertification program aimed at test facilities and their supporting systems. Facilities/systems have been prioritized as to criticality and potential hazard, and available funds are invested commensurate with that prioritization. The recertification of high pressure gas systems, pressure vessels, relief devices, flex hoses, and expansion joints is essentially complete. The recertification of the major aeropropulsion facilities is planned to coincide with other construction activities so as to minimize the programmatic impact.

CONCLUDING REMARKS

Lewis has positioned itself to have the required computational and experimental facilities to effectively undertake aeropropulsion research and technology development:

* Flow benches
* Laboratories
* Turbomachinery component rigs
* Full-scale turbine engine sea-level test stands
* Full-scale turbine engine altitude test stands
* Propulsion wind tunnels
* Aerodynamic wind tunnels
* Platform aircraft
* Desk-top, mid-size, and supercomputers

We stand ready to work cooperatively with industry, academia, and other Government agencies in our R&T efforts.